Road Tunnel Ventilation

Compendium and Practical Guideline

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Have courage to use your own understanding

Immanuel Kant, 1724-1804

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1 Preface

Tunnels represent the most expensive type of transportation infrastructure, being more elaborate to construct than open roads, bridges and other civil engineering structures. The benefits must be worth the price. In comparison to an open road, tunnels usually provide a faster and safer means of transportation, shortcutting dangerous mountain or urban roads, protecting the road users from external hazards like bad weather, rockfall and avalanches, and in return shielding the environment from the negative impact of road traffic, like noise and pollution.

The tunnel ventilation system is an important element for the operational safety of a tunnel, contributing significantly to investment and operational costs. A lot of research on road tunnel ventilation has been worked out in the 20th century. Most of the findings are still valid. In the meantime, many experts have been retired or passed away, and taken their knowledge with them.

However, in the 20th century, the focus of tunnel ventilation was on air quality in the tunnel under traffic. Vehicle pollutant emissions were a serious problem. Since the late 1990^{ies}, air quality in and around road tunnels is rarely an issue, with some exceptions, since vehicle emissions have significantly decreased in developed countries with strict emission standards. Today, most road tunnel ventilation systems are never in operation. The focus of tunnel ventilation design and operation has shifted towards smoke control in the rare event of a fire in the tunnel. Unfortunately, in some catastrophic fire incidents, the tunnel ventilation significantly contributed to the disasters by fanning the fire and increasing the spread of smoke.

In the present Road Tunnel Ventilation Compendium, comprehension of basic aspects of tunnel ventilation, in the context of general safety of road tunnels, should be advanced. Tunnel ventilation fundamentals and simple, clearly understandable und practically oriented specifications for concept, design, realization and operation of road tunnel ventilation systems shall be described. This Compendium does not comprise aerodynamic calculations, since they can be looked up in corresponding technical literature (see bibliography). Instead, open questions, common errors and ambiguities in tunnel safety and ventilation issues shall be cleared, and design hints are given, focusing on best practice when safe and reliable functionality matters.

This Compendium stems from the authors extensive practical experience in the analysis, design, implementation, commissioning, testing, and operation of tunnel safety and ventilation systems for over two decades, which in turn is based on the knowledge of many competent colleagues and predecessors, and research worked out by several generations of experts.

10 Closing remarks

More than 100 years ago, many long rail tunnels in the Alps had been equipped with powerful ventilation systems to dilute the smoke from the coal powered steam locomotives. After electrification of railways in the first half of the 20th century, those tunnel ventilation systems were not used anymore and had been removed.

Similarly, the situation in road tunnels has changed at the end of the 20th century, when vehicle emissions significantly dropped in most countries of the developed world due to strict air pollution control requirements. Before that, powerful transversal ventilation systems were required to limit exposure to toxic vehicle exhausts and achieve a sufficient visibility in long road tunnels. Today, the dilution of pollutants in and around road tunnels is rarely an issue[24]. For instance, the exhaust shaft in Fig. 20 had never been in operation. Fire ventilation has become the new design basis, even when fire disasters in road tunnels occur only rarely. Most road tunnel ventilation systems are hardly ever in operation.

There are many country-specific design standards and guidelines, where the requirements for the ventilation design and operation are more or less strictly defined; some are listed in the bibliography. However, a standard represents at most the 'state of the art' at the time when it was written, and therefore is obsolete when it becomes effective. Many standards and guidelines are not thought out in aspects of safety, cost-benefit efficiency, and practical application. Well-meant requirements may also result in unwanted side effects, which arise in practice. Few standards describe how to find and eliminate flaws and verify reliable accomplishment of goals.

In a legal investigation following an incident, the judges and lawyers consult whether the technical rules and standards have been followed. But who is responsible for the content of those standards? What about requirements that are detrimental to the safety of people and infrastructure? How far does the engineer's liability reach?

As a good example, in the NFPA standard [26] there is written: *'Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, reliability, and safety over those prescribed by this standard, provided sufficient technical data demonstrates that the applied method material or device is equivalent to or superior to the requirements of this standard with respect to fire performance and safety.'*

Best practice should be based on logical reasoning and empirical evidence from practical experience.

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[24] Exceptions are very long urban tunnels with sensitive environmental impact requirements, or tunnels in countries with a large part of vehicles without emission restrictions.

